ADVANCE SPACE TRANSPORTATION

Computational Fluid Dynamic Simulation of Space Shuttle Orbiter During Contingency Abort Maneuvers

P. Papadopoulos, D. Prabhu, M. Wright, C. Davies, R. McDaniel, J. Brown, E. Venkatapathy, P. Wercinski

To improve the safety of the space shuttle orbiter (SSO), NASA is reexamining return-to-launch-site and transatlantic abort scenarios. Ames Research Center, in partnership with Boeing Reusable Space Systems (BRSS) and Johnson Space Center (JSC), has used computational fluid dynamics (CFD) to estimate the aerodynamic loads that would be experienced by the SSO during these abort maneuvers, for which very limited information exists relating to surface pressure distributions. Ames provided 38 cases that cover the Mach number range from 3.5 to 15, angle of attack range of 20 to 60 degrees, three elevon/body-flap combinations, and two speed-brake deflections. Additionally, five benchmark cases were computed and compared with data from the Orbiter Aerodynamic Data Book (OADB), which is the rigorous standard of SSO aerodynamics.

To accommodate the variety of control-surface deflections, the grid-generation strategy implemented by Ames was to build an initial "master" volume grid with topological characteristics that allowed replacement of localized volume grids around the control surfaces without changing the rest of the grid. The resulting volume grid consists of 38 zones with approximately 2 million grid points. CFD computations were performed using the General Aerodynamics Simulation Program (GASP). The overall strategy implemented to compute the contingency abort flight conditions used methods derived from the X-33 program. Automation tools were developed for setting up the cases, checking for convergence and quality, computing surface pressure and hinge-moment data, and postprocessing the results in a format useful for aerodynamic and structural analysis. Figure 1 shows an example of a computed solution. Flooded color contours of the surface pressure coefficient are shown at conditions of Mach 15, angle of attack 50 degrees, and inboard and outboard elevons at 10 degrees trailing-edge down. This flight condition (and most of the other cases simulated) are beyond the nominal flight envelope for the shuttle but are potential contingency abort trajectory flight conditions.

An SSO aerodynamics panel was convened at JSC to review the computations and to determine their acceptability for abort assessment. The details of the CFD process, comparisons with the OADB for integrated forces and moments, and comparisons with pressure data from available ground and flight measurements were presented to the SSO aerodynamics panel. The computations agreed very well over a range of Mach numbers from 3.5 to 15.0 and of vehicle attitude ranging from 20 to 60 degrees. In a limited number of cases, differences existed between the predicted aerodynamic coefficients and the OADB data. Analysis of the CFD simulations in these cases showed unique flow physics related to the growth of the subsonic region on the windward side of the vehicle. The combined effects of Mach number and real-gas flow physics were

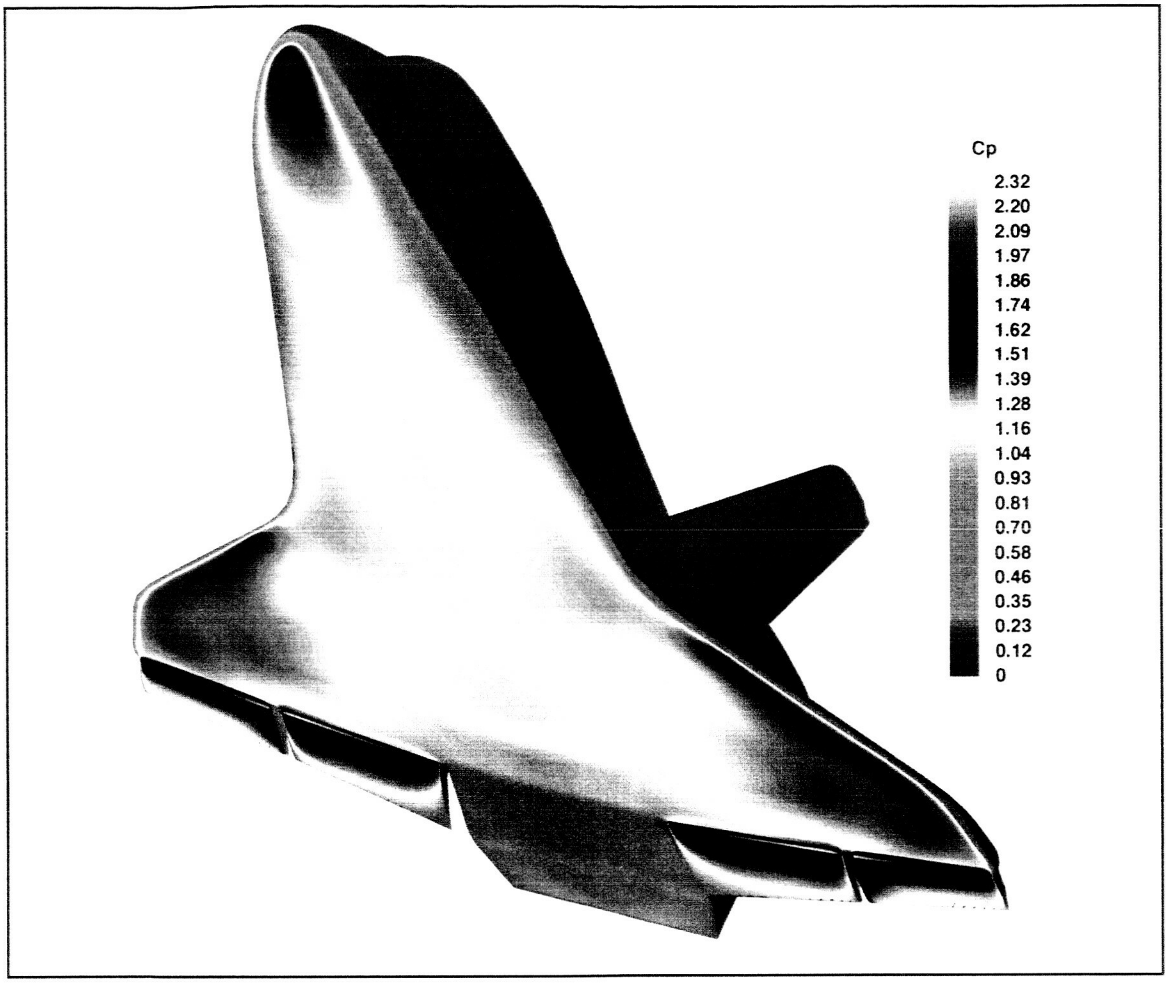

Fig. 1. Surface pressure coefficient distribution at Mach 15, 50-degree angle of attack, and elevons at 10 degrees trailing-edge down.

identified as the reason for the differences. Analysis was presented to substantiate these observations. Review of the historical development of the OADB, and in-depth analysis of the CFD solutions have led the SSO aerodynamics panel to favor the CFD solutions in the high Mach number and angle-of-attack regime. The overall good agreement between the CFD predictions and the OADB has led the Shuttle Program to accept the CFD predictions as the basis for the Orbiter Contingency Abort Data Base, an extension for the current OADB. The detailed pressure distributions generated at key abort conditions will be used as the basis for evaluating the capability of the SSO during specific abort scenarios.

Point of Contact: P. Papadopoulos
(650) 604-3477
ppapadopoulos@mail.arc.nasa.gov